Historic, archived document

Do not assume content reflects current
scientific knowledge, policies, or practices.

A99.9 F764U

Forest Service

Intermountain
Forest and Range
Experiment Station
Ogden, UT 84401

Research Paper
INT-287

May 1982

Changes in Sodium Adsorption Ratios Following Revegetation of Coal Mine Spoils in Southeastern Montana

Bland Z. Richardson
Eugene E. Farmer

THE AUTHORS

BLAND Z. RICHARDSON, research forester on the Mined-Land Reclamation research work unit at Logan, Utah, joined the staff of Intermountain Forest and Range Experiment Station in 1962. His research activities have included studies to determine the effect of multiple logging roads on moisture regimen, the hydrologic and pedologic effect of grazing on rangelands, the infiltration and erosional behavior of contour trenches on high elevation watersheds, and the effect of voids on the accuracy of neutron moisture measurements. Since 1966 his research has been exclusively on surface mine problems, evaluating research results, and furnishing recommendations to Federal and State agencies as well as private industry.

EUGENE E. FARMER, project leader of the Mined-Land Reclamation research work unit at Logan, Utah, joined the staff of the Intemountain Forest and Range Experiment Station in 1964. Since 1966 he has studied reclamation of lands mined for coal, copper, and phosphate. His primary investigations are in surface and subsurface hydrology, revegetation, and waste dump mass stability.

RESEARCH SUMMARY

This paper presents the results of a 7-year study of the magnitude of reduction in the sodium adsorption ratios (SAR) following revegetation of coal mine spoils in southeastern Montana. Results show a decrease in SAR values from greater than 12 to less than 3 resulting in an improvement in both the chemical and physical quality of sodic spoils. Results indicate that 5 to 7 years were sufficient to eliminate sodium as a serious obstacle in future vegetal development. Increases in biomass production resulting from revegetation produced further decreases in a relative proportion of sodium ions to other cations in sodic spoils at the Decker coal mine.

The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others which may be suitable.

United States
Department of
Agriculture

Forest Service

**Intermountain
Forest and Range
Experiment Station
Ogden, UT 84401**

Research Paper
INT-287

May 1982

Changes in Sodium Adsorption Ratios Following Revegetation of Coal Mine Spoils in Southeastern Montana

Bland Z. Richardson
Eugene E. Farmer

INTRODUCTION

An important problem in the Interior West is the potentially adverse effect on environmental quality of spoils left after surface mining for coal. Needed are definitions and prescriptions for revegetation treatments and post-management measures on various kinds of surface mined land. Equally important is the need for criteria and guides to predict how well such land may be revegetated. The Surface Mining Control and Reclamation Act (P.L. 95-87) and its regulations have placed new emphasis on revegetation of spoil materials at western coal surface mines. Currently, many research activities are under way to determine the best "mix" of cultural practices and plant species needed to satisfactorily revegetate disturbed land.

Surface mining for coal usually requires removal of many feet of overburden to expose the coal bed. Following removal of the coal, the overburden materials are usually redeposited as spoils. Because many surface minable coal areas in the West have alkaline, saline, or sodic soils typically found where climates are semiarid or arid, the spoil materials left after surface mining have these same or more concentrated chemical properties. The characteristics of any alkaline-saline-sodic soil or spoil material that appear to be most important in determining its ability to support plant growth are: (1) total concentration of soluble salts; (2) relative proportion of sodium to other cations; (3) concentration of boron or other elements that may be toxic; and (4) under some conditions, the bicarbonate concentration as related to the concentration of calcium plus magnesium. Among the most important of these characteristics is the relative proportion of sodium to other cations.

Sodic spoils have been identified as a problem in reclamation at a number of coal surface mine sites in the Interior West. One of these problem areas is the Decker coal mine in southeastern Montana approximately 20 miles (32 km) north of Sheridan, Wyo. Because of the uncertainty that revegetating sodic spoil materials at the Decker mine would be successful, an investigation was begun in 1972 by the Intermountain Forest and Range Experiment Station of the USDA Forest Service. Scientists sought to determine the effects of various soil amendments upon production of vegetation and the relative proportion of sodium to other cations in these sodic spoils. This study was predicated on the following hypotheses:

1. The relative proportion of sodium to other cations would decrease with time.
2. Addition of mulch, fertilizer, or both would increase production of vegetation on these sodic spoils.
3. Increase in production of vegetation would further decrease the relative proportion of sodium to other cations at the Decker mine.

METHODS

Methods used in this investigation were based on the assumption that the primary goal of revegetation of the Decker coal mine would be to establish a productive and protective cover of durable plants, consisting predominantly of species adapted to and characteristic of that area before mining. It was further assumed that differences in the degree of success of revegetation would be related to differences in the revegetation methods used. The degree to which plant cover is established can be measured and evaluated in several ways, one of the most

important of which is the capability of the vegetation to produce aboveground biomass. Therefore, the degree of success of revegetation on our research plots was measured in terms of total weight of aboveground biomass.

The research site was on spoil materials that had been graded level in order to avoid differences in erosion, runoff, evaporation, and transpiration—processes that characterize sloping sites on different aspects. The spoils originated as overburden removed from the test pit about 200 ft (60 m) from the study site.

On the study site, 48 plots, each 8 ft (2.4 m) square, were established in each of three blocks. The plots in one block were located on raw spoils and received no irrigation. The plots in a second block were also located on raw spoils and were irrigated periodically throughout the first growing season. The plots in the third block were covered with 8 inches (20 cm) of topsoil that had previously been removed from the study site (Farmer and others 1974). This paper is concerned only with the information obtained from those plots in the unirrigated block on raw spoils.

Revegetation Treatments

Twelve revegetation treatments, each replicated four times in a randomized block, were applied to the 48 plots. These treatments consisted of all possible combinations of three different grass-seed mixtures, two levels of fertilizing, and two levels of mulching.

Grass-Seed Mixtures

The three grass-seed mixtures were native species, introduced species, and a combination of native and introduced species. All native grass species used are native to the general area of Decker. The seed was collected by hand during the summer and cleaned before use. Seed for the introduced species, all of which grow successfully in the vicinity of the Decker mine, were obtained commercially. All the species used appeared to be useful for revegetation at the Decker mine site because they grew well on other disturbed sites in the area, such as road cuts, fills and old mining sites.

The native grass mixture consisted of green needlegrass (*Stipa viridula*), western wheatgrass (*Agropyron smithii*), blue grama (*Bouteloua gracilis*), little bluestem (*Andropogon scoparius*), sideoats grama (*Bouteloua curtipendula*), Indian ricegrass (*Oryzopsis hymenoides*), slender wheatgrass (*Agropyron trachycaulum*), and big bluestem (*Andropogon gerardi*).

The introduced grass mixture included fairway crested wheatgrass (*Agropyron cristatum*), Nordan crested wheatgrass (*Agropyron desertorum*), Russian wildrye (*Elymus junceus*), pubescent wheatgrass (*Agropyron trichophorum*), intermediate wheatgrass (*Agropyron intermedium*), Manchar smooth brome (*Bromus inermis*), winter rye (*Secale cereale*), and tall wheatgrass (*Agrophyron elongatum*).

The native-introduced grass mixture contained green needlegrass, western wheatgrass, blue grama, slender wheatgrass, Nordan crested wheatgrass, Russian wildrye, intermediate wheatgrass, and Manchar smooth brome.

Fertilizer

The fertilizer used as a spoil amendment was a commercial granular 15-40-5 type mixed with a silica sand carrying agent.

Mulch

The mulch used was a commercial sphagnum peat moss; it was covered by a single layer of jute netting.

Plot Preparation and Treatment Application

The surface of each study plot was prepared as a seedbed by ripping the spoils to a depth of 10 inches (25 cm), then harrowing the surface several times with a spring-tooth harrow until the spoils were friable and no large clods were present. Great care was taken to ensure that the following treatments were applied uniformly and confined to the appropriate plot area.

1. A small seed spreader was used to apply fertilizer on appropriate plots at the rate of 300 lb/acre (336 kg/ha), and the fertilizer was hand raked into the spoils.
2. All three seed mixtures were applied to appropriate plots at the rate of 25.5 lb/acre (28.6 kg/ha), and the seed was covered by hand raking the surface lightly.
3. Mulch was spread over the appropriate plots at the rate of 2.5 tons/acre (5 604.3 kg/ha) and was packed down with a Brillion cultipacker.

DATA COLLECTION

Measurements of vegetation and spoil properties were made on all 48 study plots in 1972 and in each year from 1975 through 1979. All measurements were made on the interior 6- by 6-ft (1.8- by 1.8-m) area of each plot; this separated the measurement location on each plot from that of any other plot by a buffer zone of 2 ft (0.6 m).

The dry-weight production of grass on each plot was measured every year near the time of peak vegetation development. These measurements were made with a Neal Capacitance Meter (Neal and Neal 1973) calibrated by clipping, drying, and weighing one of every six herbage plots read with the meter. The effect of weeds was eliminated by clipping them separately from the grasses and excluding their weight from all analyses.

Samples were collected from the surface foot (0.3 m) of spoils and analyzed in the laboratory to determine pH, total salt as measured by electrical conductivity (EC_e), sodium, calcium, and magnesium. The sodium, calcium, and magnesium values were used to calculate sodium adsorption ratio (SAR) values. The alkali hazard involved in soils or spoils is determined by the absolute and relative concentrations of the sodium, calcium, and magnesium cations. If the proportion of sodium is high, the alkali hazard is high; and conversely, if calcium and magnesium predominate, the hazard is low. The sodium adsorption ratio of a soil or spoil solution is simply related to the adsorption of sodium by the soil; consequently, this ratio has distinct advantages for use as an index for the sodium or alkali hazard. This ratio is defined by the equation:

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

where Na, Ca, and Mg represent the concentrations of the respective cations in mil equivalents per liter (U.S. Salinity Laboratory 1954). Generally, spoils with SAR values of less than 5 present no alkali hazard; spoils with SAR values from 6 to 9 cause some hazard; and those greater than 9 usually create a severe hazard.

Monthly prelcipitation data at Decker were summarized for the 9 years 1971 through 1979 (National Oceanic and Atmospheric Administration 1971-79.)

DATA ANALYSES AND RESULTS

Analyses followed multiple regression strategies for estimating sodium adsorption ratios as a function of both annual and growing season precipitation, fertilizer and mulch treatments, production of aboveground biomass, and time elapsed since revegetation. The simple linear effects of these independent variables on sodium adsorption ratios were examined statistically as a means of isolating the stronger variables for use in synthesizing a final regression model.

These analyses reveal that the number of years since revegetation and the production of aboveground biomass were the independent variables that added most significantly to the regression for sodium adsorption ratio. Growing season precipitation, fertilizer, and mulch were also significantly related to sodium adsorption ratios; however, when these three variables were combined with biomass production, they explained no additional significant variance in the sodium adsorption ratio beyond that explained by differences in biomass production alone. Biomass production was determined to be highly correlated with growing season precipitation, fertilizer, and mulch, and appears to be a good integrator of these variables. Accordingly, these three variables were dropped from further consideration, and a regression model was developed to describe changes in sodium adsorption ratios associated with differences in time since revegetation and variability in biomass production. These relations are expressed by the following equation:

$$SAR = 15.76443 - 3.91277(y) + 0.29564(y^2) - 0.000000072106(Y \times p^2)$$

where SAR = sodium adsorption ratio, y = number of years since revegetation, and p = pounds per acre of biomass production. This equation accounts for 95 percent of the variance in sodium adsorption ratio on these mine spoils during the first 7 years after they were revegetated.

Multiple solutions of this equation for selected biomass production values in each of the 7 years of study produced the series of regression curves shown in figure 1.

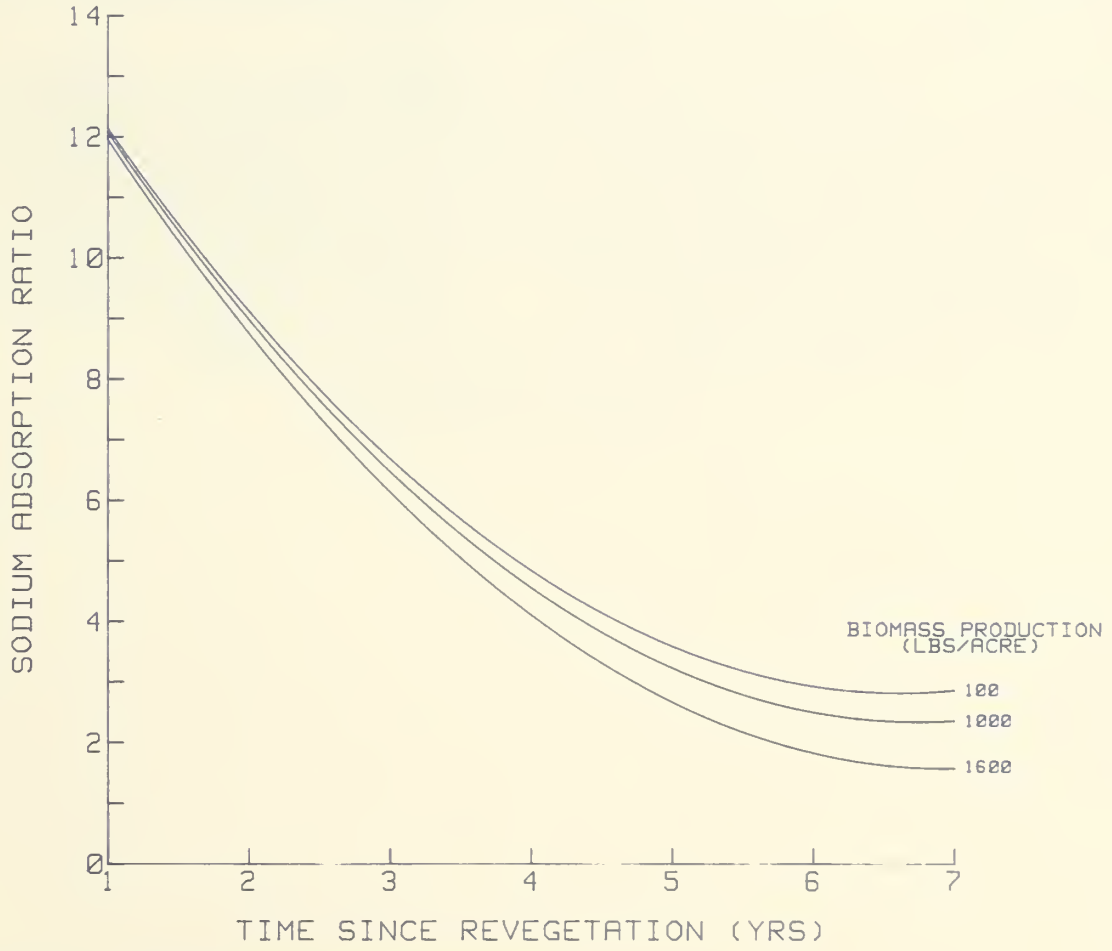

Figure 1.—Effects of time since revegetation and aboveground biomass production on sodium adsorption ratios of sodic mine spoils at Decker, Mont.

Sodium adsorption ratios consistently decreased throughout the 7 years following revegetation. Most of these decreases occurred in the first 5 years. For example, where the amount of biomass produced was a negligible 100 lb/acre (112 kg/ha), sodium adsorption ratios decreased from about 12 to 3.6 after 5 years, and to 2.8 after 7 years. While further decreases in sodium adsorption ratios might occur as revegetated stands become older than 7 years, the shape of regression curves suggest that such decreases are likely to be inconsequential. Sodium adsorption ratios also decreased as the amount of biomass produced by revegetated plant cover increased from less than 100 to more than 1,600 lb/acre (less than 112 to more than 1 792 kg/ha). The effectiveness of increased amounts of biomass for reducing sodium adsorption ratios became greater as the revegetated stands became older. For example, when the revegetated plant cover was 2 years old, an increase of biomass from 100 to 1,600 lb/acre (112 to 1 792 kg/ha) reduced the sodium adsorption ratio only 0.4—from 9.1 to 8.7. In comparison, when these stands became 7 years old, a similar increase in production of biomass resulted in a somewhat greater sodium adsorption ratio reduction of 1.1—from 2.8 to 1.7.

DISCUSSION

The pattern of reduction in sodium adsorption ratio values encountered confirms the study's first hypothesis: the relative proportion of sodium to other cations would decrease with time. These decreases are believed to be attributable to the leaching of sodium ions from the surface foot (0.3 m) of spoil materials by percolating water from rain and melting snow. The magnitude of reductions in sodium adsorption ratios—from about 12 to 3 or less—indicated improvement within 5 to 7 years in both the chemical and physical qualities of sodic spoils at the Decker mine sufficient to eliminate sodium as a serious obstacle to future vegetal development.

The revegetation treatments that produced the most biomass were those that included fertilizer, mulch, and a mixture of native and introduced grasses as components of the treatment. This confirms the second hypothesis, that the addition of fertilizer, mulch, or both would increase vegetal production on these spoils.

The reductions in sodium adsorption ratios associated with increases in production of biomass are believed due largely to increased leaching of sodium ions from the surface foot (0.3 m) of spoil materials. This came as a result of enhanced water percolation created by the enlarged root systems that accompany increased production of biomass. These relations confirm the third hypothesis, that increases in vegetal production would result in further decreases in the relative proportion of sodium ions to other cations in the sodic spoils at the Decker coal mine.

PUBLICATIONS CITED

Farmer, E. E.; Brown, R. W.; Richardson, B. Z.; Packer, P. E. Revegetation research on the Decker coal mine in southeastern Montana. Res. Pap. INT-162. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1974. 12 p.

Neal, D. L.; Neal, J. L. Uses and capabilities of electronic capacitance instruments for estimating standing herbage. J. Brit. Grassland Soc. 28:81-89; 1973.

National Oceanic and Atmospheric Administration. Climatological data. Asheville, N.C.: Environmental Data and Information Center; 1971-79.

U.S. Salinity Laboratory Staff. Diagnosis and improvement of saline and alkaline soils. Handb. 60. Washington, D.C.: U.S. Department of Agriculture; 1954. (Richards, L. A., ed.)

Richardson, Bland Z.; Farmer, Eugene E. Changes in sodium adsorption ratios following revegetation of coal mine spoils in southeastern Montana. Res. Pap. INT-287. OGden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1982. 4 p.

The magnitude of reductions in sodium adsorption ratios of coal mine spoils following revegetation at the Decker coal mine in southeastern Montana indicates improvement in both the chemical and physical quality of sodic spoils within a 5- to 7-year period. This reduction is sufficient to eliminate sodium as a serious obstacle in future vegetal development. Increases in biomass production resulting from revegetation produced further decreases in a relative proportion of sodium ions to other cations in sodic spoils at the Decker coal mine.

KEYWORDS: sodium soils, alkali soils, saline soils, revegetation research, surface mine revegetation, coal mine reclamation, Northern Great Plains

NATIONAL AGRICULTURAL LIBRARY
1022967132

The Intermountain Station, headquartered in Ogden, Utah, is one of eight regional experiment stations charged with providing scientific knowledge to help resource managers meet human needs and protect forest and range ecosystems.

The Intermountain Station includes the States of Montana, Idaho, Utah, Nevada, and western Wyoming. About 231 million acres, or 85 percent, of the land area in the Station territory are classified as forest and rangeland. These lands include grasslands, deserts, shrublands, alpine areas, and well-stocked forests. They supply fiber for forest industries; minerals for energy and industrial development; and water for domestic and industrial consumption. They also provide recreation opportunities for millions of visitors each year.

Field programs and research work units of the Station are maintained in:

Boise, Idaho

Bozeman, Montana (in cooperation with Montana State University)

Logan, Utah (in cooperation with Utah State University)

Missoula, Montana (in cooperation with the University of Montana)

Moscow, Idaho (in cooperation with the University of Idaho)

Provo, Utah (in cooperation with Brigham Young University)

Reno, Nevada (in cooperation with the University of Nevada)

☆ U.S. GOVERNMENT PRINTING OFFICE: 1982—576-026/149 REGION No. 8